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Proceedings of the American Academy of Arts and Sciences.

Vol. XLVIII. No. 15. — January, 1913.

AN ELECTRIC HEATER AND AUTOMATIC THERMOSTAT.

By A. L. Clark.

Investigations on Light and Heat published with Aid from the Rumford Fund.

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AN ELECTRIC HEATER AND AUTOMATIC THERMOSTAT.

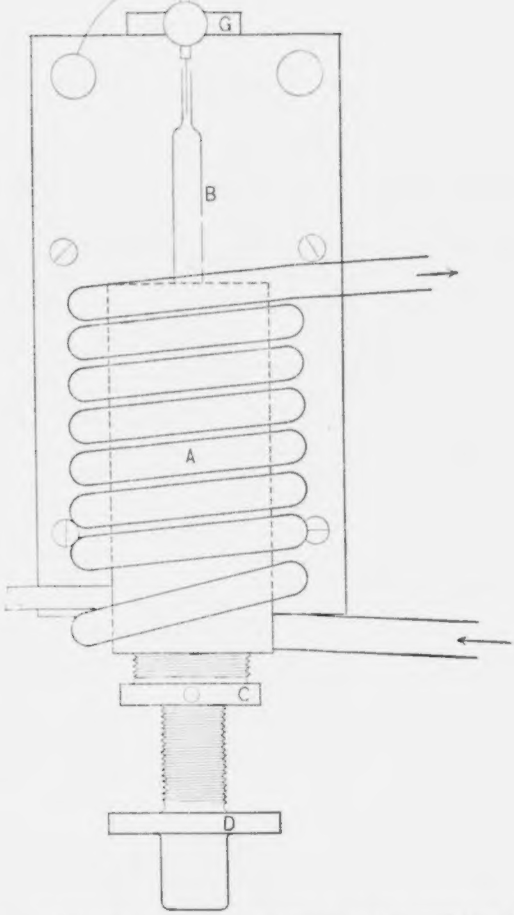
By A. L. Clark.

Received October 9, 1912.

In a previous paper [1] I have described a form of electric heater and automatic thermostat for control of temperature, capable of a fair degree of accuracy and possessing a wide range. This has been improved recently so that the accuracy with which the heater may be maintained at any given temperature is very much increased. For the work described in the paper mentioned, it was not necessary to regulate more closely than 1/10°, but subsequent work developed the need for a higher degree of accuracy with certainty of operation, and with no sacrifice of range or capacity. The following is a description of the improved apparatus. It is given because this form of heater and thermostat seems to combine accuracy of control, ease of adjustment, wide range and large size of heating spaces as does no other — at least the writer knows of none.

As mentioned in the previous paper, the device is a modification of the thermostat used by Griffith [2] in his work on the Mechanical Equivalent of Heat. The essential features are as follows: — a cubical cast-iron box 15 cm. on an edge is made with hollow walls and bottom, the solid parts of the walls being 6 mm. thick, while the hollow space is of the same thickness. In this way a chamber is formed in the walls and bottom whose volume is 420 c. c. This is filled with mercury and forms the bulb of a gigantic thermometer, the tube of which is outside the apparatus. This cast-iron box with its enclosed mercury is surrounded by coils of German silver wire, and placed within a larger box for heating. The air in this space is kept in constant and rapid motion by a number of fans, so that the entire space is maintained at uniform temperature. This apparatus is lagged with magnesia and enclosed again in a massive wooden box. It is perhaps unnecessary to state that the body to be heated is placed inside the inner cast-iron box, which is provided with windows of ample size both in front and rear, as are also the enclosing boxes, so that observation is always possible. The outer windows have covers that may be closed to investigate effects of radiation. The mercury space of the inner box is connected by a steel tube with the automatic part of the apparatus which is shown in Fig. 1.

1 These Proceedings, **41,** No. 16, Jan. (1906).
2 Griffiths, Phil. Trans., **184,** 361 (1893).



E. is the steel tube from the mercury space of the cast-iron box. A. is a cylindrical cast-iron chamber or reservoir, opening at the top into the glass tube B, and closed at the bottom by the stuffing box C, into which the screw D may be turned. When the temperature is varied the mercury within the heater expands filling the chamber A and rises eventually into the tube B, until it reaches the end of a platinum wire. This completes the circuit of a relay which cuts off the heating current, either entirely or in part. When the current is cut off, the temperature falls until contact of the relay is broken at the platinum point, when the heating current is thrown on again. If the current is properly adjusted and the change in value caused by the action of the relay be small, the amount through which the temperature rises and falls may be very small indeed. Obviously the temperature at which the relay cuts off the current depends on the actual volume of the reservoir A, or in other words on the position of the screw D. The total capacity of the reservoir is about 18 cm. which equals the expansion of the mercury in heater caused by an elevation in temperature of about 300°. Of course the amount of current used depends on the temperature at which the work is to be done and no more than is actually necessary is used.

When the proper amount of current is used the regulation near 20 is within 1/10° when the entire current is cut off. The adjustment for this accuracy need not be very carefully made. When a portion only of the current is cut off and the adjustment be made with sufficient care the variation in temperature may be made very small. Close regulation at low temperature is much easier than at higher and there is less need of careful adjustment; as the temperature is carried higher regulation becomes more difficult. One source of difficulty in maintaining constancy of temperature is due to the fact that heat is conducted along the mercury in the steel tube connecting the mercury chamber with the reservoir attended by a rise of temperature of the mercury in the reservoir. This rise in temperature has been obviated by surrounding the reservoir with a coil of small lead tubing (shown in Fig. 1) through which a current of cold water is kept circulating.

The table shows the values of the currents necessary to maintain the heater at different temperatures:—

Amps.	*Temp.*
1.43–1.55	67.2
2.35–2.45	100.6
2.88–3.05	198.0
4.30–4.40	221.0

At 198° with the regulator changing the current from 2.88–3.05 a thermometer graduated to 1/5° was watched through a microscope and no motion of the thread was apparent. The regulator worked at about two-minute intervals. One very serious difficulty which gave trouble for a long time was with the lubrication of the bearings of the shafts, driving the fans in the inner box. Ordinary lubricating oils boil out of the bearings at about 180° and condense on the windows of the outer box, obscuring the view of the inside of the box. Below about 180° there is no trouble but above this the distillation of oil occurs. Various oils were tried with no success because there is always this distillation at some temperature. Finally the difficulty was overcome by using paraffin wax which melts at about 50° and does not distil away enough to cause any trouble. Small pieces are placed in the ends of the oil tubes leading to the inner bearings. These are quickly melted by the heat conducted from within and run down to the bearings lubricating them very efficiently. The slight jarring of the whole apparatus causes trembling of the mercury at the relay contact and no sticking of the mercury to the platinum point has been noticed. A little alcohol on top of the mercury helps to keep it clean.

Not only is it important that there shall be no unsteadiness of tem-

perature but there must be no temperature gradients inside the box, more particularly vertical gradients. So an investigation of the distribution of temperature was made. The mercury thermometer was found to be worthless for this work as it does not show very small changes readily. Accordingly a platinum resistance thermometer made by Mr. C. H. Day was used. This is made of about 50 cm. of platinum wire fused on to platinum leads. The resistance wire is wound on a small mica frame in the form of a cross. The cross was first made and cemented together with "cementium." Two slits were cut in the mica, the platinum wire doubled and the loop in the end caught in the slit. Then the wire was wound on double in small cuts in the mica and finally fused to the platinum leads in the oxyhydrogen flame. The two thermometer leads together with the compensating leads were thrust through small mica discs, and the whole placed in a thin walled glass tube. The tube was slightly enlarged at the top so that it might hang in a hole in a piece of vulcanized fibre. Flexible cords were then soldered to the platinum leads and finally a second piece of fibre was fastened to the first by screws holding tube and leads firmly. The compensating leads are connected in series with a good resistance box and the two sets are connected to a slide wire bridge of the circular drum type made by the Leeds and Northrup Co.

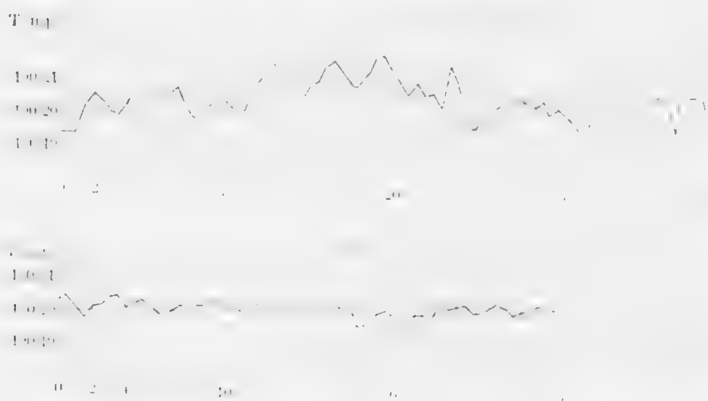
A steady current of .007 amps. is allowed to flow through the thermometer so that it is always slightly higher in temperature than its surroundings, but the amount is very small and is constant. The thermometer was calibrated by immersing in melted ice, in steam, and finally in vapor of boiling aniline which had been redistilled several times. The calibration curve compares very favorably with those given by Callendar. As the thermometer is used, one small division on the galvanometer scale corresponds to a change in temperature of about 1/120° so that the thermometer is easily read to 1/1000°. The platinum thermometer surpasses the mercury thermometer in its ability to follow small changes in temperature, and while the scale of this thermometer in the higher region may be in doubt by as much as 1/10°, its efficiency is in no way impaired. During the warming up stages in any experiment, the current for heating is taken from the 110 volt dynamo circuit, but this is too unsteady for accurate work. So when the temperature rises near the desired point the 110 volt storage battery circuit is thrown in. For work requiring 1/10° accuracy the lighting circuit is ordinarily steady enough.

It is extremely doubtful if the readings of most mercury thermometers can be relied upon to 1/100th of a degree when working at temperatures as high as 200°. The amount of stem exposed, sticking

of mercury, etc., bring its indications under suspicion. With the platinum thermometer just described, it is possible to follow fluctuations which ought to be visible in the mercury thermometer, but which are not as a matter of fact. Much interesting and valuable information was gained by use of this instrument. It was discovered that the incandescent lamp behind the box used for illumination caused a rise in temperature of over 1/10°. A lamp in the room which shone into the front window affected the temperature of the thermometer noticeably. For work on liquids near the critical point this fact must not be overlooked. It is essential that the very smallest amount of light possible be used, particularly when the light shines on a portion only of the tube, which contains the liquid under experiment. Most observers have not taken sufficient pains in this matter. Many tests for constancy of temperature have been made. The following (Table I) may be regarded as typical, and show the possibilities of the apparatus. The first set (Temp. I) was obtained by breaking the entire current of 3.96 amperes, the second (Temp. II) when the current varied between 2.62 and 3.90 amperes.

Time in Minutes	Temp. I.	Temp. II.	Time in Minutes	Temp. I.	Temp. II.
0	190.194	190.203	15½	.210	.201
½	.194	.204	16	.215	.199
1	.194	.201	16½	.218	.203
1½	.202	.198	17	.212	.201
2	.206	.200	17½	.208	.203
2½	.203	.202	18	.208	.200
3	.200	.203	18½	.212	.197
3½	190.199	190.204	19	.217	.197
4	.202	.201	19½	.218	.200
4½	.207	.202	20	.213	.201
5	.203	.203	20½	.210	.200
5½	.201	.202	21	.206	.196
6	.203	.200	21½	190.209	190.200
6½	.205	.199	22	.205	.200
7	.207	.201	22½	.207	.198
7½	.200	.202	23	.201	.203
8	.200	.201	23½	.215	.202
8½	.200	.201	24	.210	.202
9	.202	.201	24½	.197	.203
9½	.205	.202	25	.197	.201
10	.202	.201	25½	.200	.201
10½	.200	.201	26	.202	.202
11	.200	.201	26½	.204	.203
11½	190.208	190.202	27	190.201	190.202
12	.210	.202	27½	.206	.200
12½	.216	.202	28	.205	.201
13	.215	.202	28½	.203	.203
13½	.212	.198	29	.205	.203
14	.204	.202	29½	.200	.203
14½	.202	.202	30	.202	.201
15	.209	.201			

If the apparatus could be attached to a storage battery on which there were no other loads, it would be comparatively easy to get closer regulation by using a narrower range of current variation. The battery used in these experiments is liable to have other loads thrown on at any time. The curves (Fig. 2) show the variations plotted from the tables.



Next the existence of a vertical temperature gradient was examined. Readings on thermometer were made at different levels and no sure difference of temperature was observable when the space inside heater is empty. When masses of metal or other obstructions were placed inside, slight differences amounting to one thousandth of a degree were observed. In experiments like this all the windows in the apparatus must be covered as radiation causes noticeable differences in temperature.

The platinum thermometer led to another important discovery. Even after the automatic controlling apparatus becomes steady it was found that the temperature of the air inside the heater continues to rise. This is due to the fact that altogether the wall of the heater box is about 1.8 cm. thick and while the *mean* temperature of the mercury in the wall does not vary, the temperature of the inner part and the wall adjacent to it is rising while that of the outer part is falling. This rise may amount to more than .1° and it is a matter of an hour or so before it disappears. This time has been shortened by placing a small flat heating coil of fine GS wire along the inner wall inside. A small current sent through this helps to establish equi-

librium a little more quickly. Considerable judgment must be exercised in its use however.

Finally the effect of the stirring system was investigated and it was found that running at normal speed, the fans gave a rise in temperature of about .1° per hour; so that any slight variation in speed of fans is not important, but great variations may interfere with close regulation.

The ease with which one temperature after another can be obtained is one of the features of the apparatus. Other advantages are the wide range of available temperatures, the precision with which any given temperature may be reached and maintained, the large volume of heating chamber, ease of observation and the certainty of operation. Another advantage in work near the critical point is the small amount of damage caused by explosion. The windows, which are easily replaced, may be blown out but no injury to the essential parts has ever occurred and explosions have not been infrequeat.

Queen's University,
Kingston, Ontario.

VOLUME 47.

Continued on page 2 of Cover.

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